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The Mechanisms of Epilepsy: The merging of Mathematics, Neurobiology and Technology.

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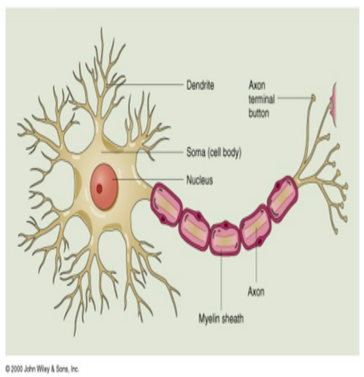
Abstract

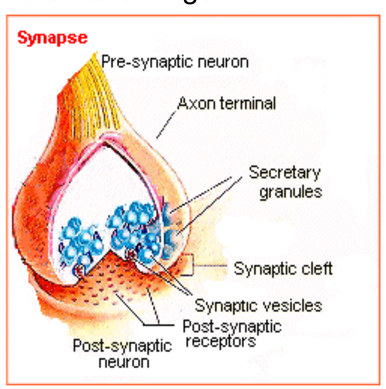
Epilepsy is one of the well- known brain disorders and the least understood of them all. The neuroscience research is helping in understanding the brain, its functions, as well as its disorders. The integration of mathematics, neurobiology and technology is becoming essential to studying the brain disorders including epilepsy. In this research, I explore the mechanisms of epilepsy and the roles that mathematical modeling plays in investigating some of the epilepsy's characteristics such as the theta band connectivity, intrinsic neuronal properties of population firing, and the topology of the neural networks .

Background



The components of the neuron are the soma, dendrites, and axon. The soma is the cell body and the processor of the neuron. The dendrites are the synaptic input path of the neuron and the axon is the synaptic output path of the neuron. The Axon hillock is the location of the neuron where the axon and the synapse meet.

The action potential or spike in response to both chemical and electrical stimulation. The action potential travels along the axon of the neuron to the end of the axon called the synaptic bouton. At this point there change in membrane potential signals the synaptic vesicles. This causes neurotransmitters or a chemical to be released from the synaptic vesicles into the synaptic cleft which binds loosely to the receptors. This causes the membrane structure to open ion channels which allow the ion concentration inside the neuron to change.



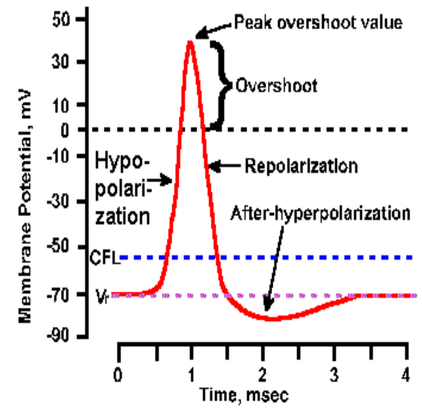
Introduction

Epilepsy refers to the disorders of the brain function which is characterized by periodic and unpredictable occurrence of seizures. A Seizure is referring to a transient change of behavior due to the disordered, synchronous and the rhythmic firing of the populations of CNS neurons. The behavior that occurs during a seizure is determined by normal functions of the cortical sites where the seizure occurs.

Electroencephalograms (EEG) measures mostly the currents that flow during the synaptic excitations of the dendrites of many pyramidal neurons in the cerebral cortex.

Process of Depolarization

Hyper-polarization : Once the membrane potential reaches a threshold value, there is a large spike (action potential) in membrane potential which is immediately followed by a steep decreased in membrane potential. after hyper-polarization: Following the period of hyperpolarization is a period of time where the membrane potential increases slightly. Refractory period of the neuron: During the period of time of HP and AHP, it is difficult to cause the neuron to fire.



Leaky –integrate and – fire Model (LIF)

The LIF model is defines the membrane potential as an injected current noise as equation below

$$\frac{dV}{dt} = V_{leak} - V + I_{syn} + \xi$$

The spike rate of the LIF Model is defined as the strength of the current input of the neurons which is stated in the equation to the right

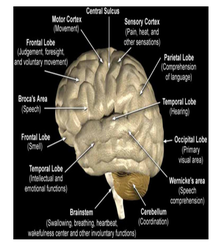
Spike rate $= \frac{f_s}{n}$

Were $n = ceil\left(\frac{ln\left(\frac{v_{th}-(V_{leak}+I)}{v_{reset}-(V_{leak}+I)}\right)}{ln(1-dt)}\right)$

ξ	Injected noise
V	Membrane potential
V_{leak}	Leakage potential and resting potential for LIF model
$V_{threshold}$	Threshold voltage for neuron firing
V_{reset}	Membrane potential reset value
I_{syn}	Synaptic current input

$$for\ I \epsilon \left(v_{th} - v_{leak}, \frac{v_{th}-V_{reset}}{dt} + v_{reset} - v_{leak}\right)$$

$$f_s \frac{1}{dt\ x\ 10^3} = \frac{10^3}{dt}$$



Cerebellum consists of the right and left hemisphere with the high convoluted surfaces layer called cerebral cortex. **Cerebrum** coordinates of the functions of movement initiation, conscious sensation, complex analysis and the expressions of emotion and behavior The **brain stem** controls the function of respiration, heart regulations, biorhythms, neurohormone and hormone secretions

Summary

- Epilepsy is one of most common brain disorder but it still much unknown.
- Model such as the depolarization, Leaky integrate and fire models as well as the brain mechanics can help to understand this disorder.

SOURCE

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